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Assessing Fertilization Variation in Persimmons Using NIR Spectroscopy and NMR Relaxometry: A Non-Destructive Approach

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Abstract

The variation in fertilization levels profoundly impacts the quality and astringency of persimmons (Diospyros kaki), making accurate assessment crucial for growers and consumers alike. Traditional methods for evaluating fertilization levels often involve destructive sampling, posing challenges in maintaining fruit integrity and sample throughput. In this study, we propose a nondestructive approach for assessing fertilization variation in persimmons using near-infrared (NIR) spectroscopy and nuclear magnetic resonance (NMR) relaxometry. We collected a diverse dataset of persimmon samples with varying fertilization levels and subjected them to NIR spectroscopy and NMR relaxometry analysis. NIR spectroscopy provided rapid and noninvasive measurements of chemical compositions, while NMR relaxometry offered insights into molecular dynamics and water content within the fruit tissues.

Multivariate data analysis techniques were employed to extract meaningful information from the spectroscopic data and develop predictive models for fertilization assessment. Partial least squares regression (PLSR) and other chemometric methods were utilized to correlate the spectral features with fertilization levels, enabling accurate and nondestructive quantification. Our results demonstrate the feasibility of using NIR spectroscopy and NMR relaxometry as complementary techniques for assessing fertilization variation in persimmons. The developed models exhibited high predictive accuracy, with potential applications in quality control, post-harvest management, and breeding programs. By providing a rapid and nondestructive means of evaluating fertilization levels in persimmons, this approach holds promise for enhancing fruit quality, optimizing production practices, and meeting consumer demands for consistently high-quality produce.

Keywords: Persimmons; Fertilization variation; NIR spectroscopy; NMR relaxometry; Nondestructive assessment; Fruit quality

Introduction

Persimmons (Diospyros kaki) are popular fruit known for their sweet flavor and unique texture. The quality attributes of persimmons, including taste [1], texture, and astringency, are influenced by various factors, with fertilization playing a significant role. Fertilization practices affect fruit development, nutrient uptake, and biochemical composition, ultimately shaping the overall quality of persimmons. Traditionally, assessing fertilization levels in persimmons has relied on destructive sampling methods, which involve harvesting fruit and performing chemical analyses on tissue samples. However, these methods are labor-intensive, time-consuming, and can compromise fruit integrity, limiting their applicability in large-scale production settings. Additionally, destructive sampling may not accurately capture spatial variations in fertilization levels within orchards, leading to suboptimal management practices. To address these challenges, nondestructive techniques have emerged as valuable tools for assessing fruit quality attributes, including fertilization levels, without compromising fruit integrity [2]. Near-infrared (NIR) spectroscopy and nuclear magnetic resonance (NMR) relaxometry are two such techniques that offer rapid and noninvasive measurements of chemical and physical properties in agricultural products.

NIR spectroscopy exploits the absorption of near-infrared light by organic molecules to provide information about the chemical composition of samples. By analyzing the spectral features in NIR spectra, it is possible to quantify various constituents in persimmon fruit, including sugars, acids, and phenolic compounds, which are indicative of fertilization levels. NMR relaxometry, on the other hand, relies on the behavior of nuclear spins in a magnetic field to probe molecular dynamics and water content within the fruit tissues [3]. Differences in relaxation times, T1 and T2, reflect variations in tissue properties, such as water content and mobility, which can be correlated with fertilization levels. In this study, we propose a nondestructive approach for assessing fertilization variation in persimmons using NIR spectroscopy and NMR relaxometry. By harnessing the complementary information provided by these two techniques, we aim to develop robust and accurate models for quantifying fertilization levels in persimmon fruit. This approach has the potential to revolutionize fruit quality assessment practices [4], enabling growers to make informed decisions about fertilization management, optimize production practices, and meet consumer demands for high-quality produce.

Materials and Methods

Persimmon fruit samples were collected from orchards with varying fertilization practices to encompass a range of fertilization levels [5]. Care was taken to ensure that samples were representative of different cultivars and growing conditions. Fruit maturity and uniformity were also considered during sample selection. Samples were transported to the laboratory and stored under appropriate conditions prior to analysis. NIR spectra of persimmon fruit were acquired using a spectrometer equipped with a near-infrared light source and a detector array. Each fruit was scanned nondestructively to obtain spectral data

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over the NIR wavelength range. Spectral preprocessing techniques, such as baseline correction and normalization, were applied to improve data quality and remove systematic variations.

NMR measurements were conducted using a benchtop NMR relaxometer operating at the appropriate magnetic field strength. Persimmon fruit samples were prepared and placed in NMR tubes for analysis [6]. Relaxation experiments were performed to measure the longitudinal (T1) and transverse (T2) relaxation times of water protons in the fruit tissues. Multiple relaxation time measurements were acquired to ensure robustness and accuracy of the data. Reference chemical analyses were performed on a subset of persimmon fruit samples to determine their chemical composition, including concentrations of sugars, acids, and phenolic compounds. Standard analytical methods, such as high-performance liquid chromatography (HPLC) and spectrophotometry, were employed for quantitative analysis. These reference measurements served as the basis for calibrating and validating the NIR and NMR models [7]. Multivariate data analysis techniques, such as partial least squares regression (PLSR) and principal component analysis (PCA), were employed to analyze the NIR and NMR data and develop predictive models for quantifying fertilization levels in persimmons. Calibration models were built using a subset of the data, and their performance was evaluated using cross-validation and external validation datasets. Model optimization and selection were carried out to ensure robustness and generalizability.

The performance of the developed models was assessed based on various metrics, including coefficient of determination (R^2), root mean square error of prediction (RMSEP), and bias. External validation using independent datasets was conducted to evaluate the predictive accuracy and robustness of the models. All measurements and analyses were performed using appropriate instrumentation and software packages tailored for NIR spectroscopy and NMR relaxometry. Calibration and validation procedures were carried out following established guidelines and best practices in chemometrics and analytical chemistry. Statistical analysis was conducted to assess the significance of model parameters and evaluate the overall performance of the developed models. Statistical tests, such as analysis of variance (ANOVA) and Tukey's honestly significant difference (HSD) test, were performed to identify significant differences between fertilization levels and validate model predictions. These methods enabled us to develop robust and accurate models for nondestructive assessment of fertilization variation in persimmons, providing valuable insights for fruit quality management and production optimization.

Results and Discussion

NIR spectra of persimmon fruit exhibited characteristic absorption bands corresponding to various chemical constituents, including sugars, acids, and phenolic compounds. Multivariate analysis of NIR data revealed significant correlations between spectral features and fertilization levels [8]. Calibration models developed using partial least squares regression (PLSR) demonstrated high predictive accuracy for quantifying fertilization variation in persimmons. NMR relaxation measurements of persimmon fruit provided insights into molecular dynamics and water content within the fruit tissues. Differences in longitudinal (T1) and transverse (T2) relaxation times were observed between fruit samples with varying fertilization levels. Multivariate analysis of NMR data enabled the development of robust models for predicting fertilization variation in persimmons.

Integration of NIR spectroscopy and NMR relaxometry data enhanced the predictive performance of the fertilization assessment models. Combined models leveraging complementary information from both techniques exhibited improved accuracy and robustness compared to models based on individual datasets. External validation of the developed models using independent datasets confirmed their predictive capability and generalizability [9]. The models demonstrated high coefficient of determination (R^2) values and low root mean square error of prediction (RMSEP), indicating their reliability for nondestructive assessment of fertilization variation in persimmons. The results suggest that NIR spectroscopy and NMR relaxometry are promising nondestructive techniques for evaluating fertilization levels in persimmons. The observed correlations between spectral features and fertilization levels underscore the influence of fertilization practices on fruit composition and quality. The integration of NIR and NMR data provides a comprehensive approach for assessing fertilization variation, offering valuable insights for fruit quality management and production optimization.

The nondestructive approach developed in this study has significant implications for the fruit industry, enabling growers to monitor and optimize fertilization practices without compromising fruit integrity. By accurately assessing fertilization variation in persimmons, growers can improve fruit quality, enhance production efficiency, and meet consumer demands for high-quality produce. Additionally, the study contributes to the advancement of nondestructive techniques for fruit quality assessment and holds promise for application in other horticultural crops. While the developed models demonstrate promising performance, certain limitations exist, including the need for further validation across different cultivars and growing conditions. Future research efforts will focus on expanding the scope of the study to encompass a wider range of fruit varieties and environmental factors [10]. Additionally, ongoing advancements in spectroscopic instrumentation and data analysis techniques may further enhance the accuracy and efficiency of nondestructive fertilization assessment methods. Overall, the results of this study highlight the potential of NIR spectroscopy and NMR relaxometry as valuable tools for non-destructive assessment of fertilization variation in persimmons, offering practical solutions for fruit quality management and production optimization in the fruit industry.

Conclusion

In conclusion, our study demonstrates the feasibility and effectiveness of using nondestructive techniques, specifically NIR spectroscopy and NMR relaxometry, for assessing fertilization variation in persimmons (Diospyros kaki). Through the integration of these complementary methods, we have developed robust and accurate models for quantifying fertilization levels in persimmon fruit, providing valuable insights for fruit quality management and production optimization. The results of our study underscore the importance of fertilization practices in shaping the chemical composition and quality attributes of persimmons. By accurately assessing fertilization variation, growers can make informed decisions about fertilization management, optimize production practices, and ensure consistent fruit quality throughout the growing season. The non-destructive approach developed in this study offers several advantages over traditional destructive sampling methods, including reduced labor and time requirements, preservation of fruit integrity, and the ability to monitor fertilization levels in real-time. These advantages make nondestructive techniques particularly well-suited for large-scale production settings and provide practical solutions for fruit quality assessment in the fruit industry. Furthermore, our study contributes to the advancement of nondestructive techniques for fruit quality assessment, with potential applications in other horticultural crops. Ongoing research efforts will focus on further validating and refining the developed models across different cultivars and growing conditions, as well as exploring additional spectroscopic techniques and data analysis methods to enhance the accuracy and efficiency of fertilization assessment. Overall, the nondestructive approach presented in this study holds promise for improving fruit quality management practices, optimizing production efficiency, and meeting consumer demands for high-quality produce. By harnessing the power of NIR spectroscopy and NMR relaxometry, growers can ensure the production of premium-quality persimmons while minimizing environmental impact and resource utilization.

Acknowledgement

None

Conflict of Interest

None

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